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# Computing in the classroom: Tales from the chalkface

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**Abstract:** Computing, a broad discipline including computer science, information technology and digital literacy, was introduced as a mandatory national curriculum subject in England in 2014. This meant the introduction of both computer programing and more academic computer science into the curriculum. Such a significant curriculum change involves a period of transition, lasting several years. Here we consider what we have learned about the implementation of the new curriculum, the external influences that have come to bear on teachers' and pupils' experiences, and the challenges that are faced.

**Keywords:** computer science education, primary education, secondary education, K-12 teachers

**ACM CCS:** Social and professional topics → K-12 education

## 1 Introduction

England introduced a new Computing curriculum to schools in 2014. This built on, but was broader and more focused on computer-science than, the previous ICT curriculum [4]. Computing thus became mandatory as a school subject for all children aged 5 to 16 in schools following the national curriculum. At the time of writing, England has three years of experience of the implementation of Computing in school, which has presented both exciting opportunities and some tough challenges.

The Berlin model [30] enables us to consider different aspects of the educational process and climate from a range of different perspectives. In this article we consider the anthropological and psychological aspects of the development of Computing as a school subject. This will include motivational, behavioural and attitudinal aspects, pupil and teachers' background in knowledge and skills and the learning and progression of pupils in this subject area. We look at the effect of different groups involved in the educational landscape and their impact on computing in school. We consider how early experiences in England contribute to a broader understanding of computer science teaching in school, and the challenges that are evident. Although limited evidence has yet emerged, we consider what we know about how children are developing their computer science skills since this significant introduction of Computing as a mandatory subject, and highlight the need for more research into primary and secondary computing education.

## 2 Context

Computer science (CS) education has been generating increasing interest as a school subject in the last few years. Some countries such as Israel, Lithuania and Poland have been teaching CS in school for several decades, but for others there has been a more recent shift from computer and ICT applications towards rigorous academic computing – a summary and comparison of these can be seen in [13].

In England prior to 2014, pupils studied ICT as a mandatory subject in school from age 5–16. This included an element of programming referred to as control. However, the emphasis was on cross-curricular use of technology, such as word processors, art packages and spreadsheet tools with suggested lesson material provided by the Qualification & Curriculum Authority.[1] ICT had been in the curriculum since 1999 and was relatively stable. However the provision was considered to be highly unsatisfactory with the Royal Society's influential *Shut Down Or Restart* report finding that "many pupils are not inspired by what they are taught and gain nothing beyond basic digital literacy skills" [28] and that the ICT curriculum was neither a suitable transition into further study of the subject or a good preparation for skills needed in the workplace (whether in IT-related employment or not).

In K-5 classrooms, ICT had been taught by generalist classroom teachers who may have had some initial teacher

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1 The Qualification and Curriculum Authority regulated UK qualifications in the 1990s.

training or in-service training related to the ICT. For older learners ICT had been taught by ICT specialist teachers. In 2010, only 25 % of secondary ICT teachers held both a relevant degree and teaching qualification [28]. In 2011 ICT teachers' subject knowledge was found to be weakest in data logging, manipulating data and programming [18]. Thus urgent change was needed.

The development of Computing for all children is not just an issue of providing suitably qualified IT professionals from the education system. There are compelling reasons for mandatory computing for all children in addition economic and employment reasons. Firstly, we can consider the learning of computing an equity issue. The recent curriculum framework for Computing launched in USA states that "Computer science for all students requires that equity be at the forefront of any reform effort" [14]. Similarly, the English national curriculum requires that "all pupils: can understand and apply the fundamental principles and concepts of computer science and all pupils can analyse problems in computational terms and have repeated practical experience of writing computer programs to solve problems" [9]. These requirements bring with them the need to challenge stereotypes around who is able to study computing. We need to prepare all young people for a world full of technology that does not yet exist; and ensure that an understanding of technology is an entitlement not a privilege. This goes beyond basic digital skills because our changing world means that a more thorough understanding of how and why computers influence every aspect of our lives is needed.

Secondly, the discipline of computer science engages certain ways of thinking, broadly referred to as computational thinking skills [31], which are useful for the kind of problem-solving involved in computational subjects [27]. This extends to the computational analysis, design and algorithmic thinking involved in a range of subject areas such as science, engineering, medicine, finance and economics, all increasingly using computational modelling. Even more broadly, proponents of the computing curriculum in England have argued that the development of these thinking skills, while not transferable [12], would prepare students for the kind of problem solving they will need to be doing in the modern world regardless of vocational or academic interest [20].

In England the new curriculum was introduced in September 2014 with great optimism and excitement, as well as media interest both nationally and internationally. Children study computer science, information technology and digital literacy, together making up the subject Computing. This change has seen the development of many new resources, teaching schemes, textbooks, tools and environments to support the curriculum in the classroom. Much of the content remains from the previous curriculum – new content mostly relates to aspects of computer science and includes algorithms and programming, networking, how computers work, binary number systems and logic.

The aims of the new curriculum are that all pupils:
- can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation
- can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve such problems
- can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems
- are responsible, competent, confident and creative users of information and communication technology [9]

Mandatory computing has several implications: firstly, it needs to be appealing and engaging to all children, including those who would not choose extra-curricular Computing if offered, and particularly those who are typically under-represented in computing; secondly, it needs to be academically accessible to all children, including those with special educational needs; thirdly, many more teachers will be needed with a good understanding of computing at the level at which they teach.

# 3 Breadth of influences

One of the factors that makes Computing in the curriculum distinct from other subjects in school is the wealth of interested parties who have influence and agendas relating to this subject area. Figure 1 shows the many different groups who have an interest or stake in what happens in computing education in school.

## 3.1 Government

Due to devolution within the UK there are separate departments of education in England, Wales, Northern Ireland and Scotland. Different curricula and examination arrangements exist in each country. In this paper we are focusing primarily on England where the new curriculum was introduced: startling in its brevity, it is simply a short list of topics to be delivered at each stage of school. This is

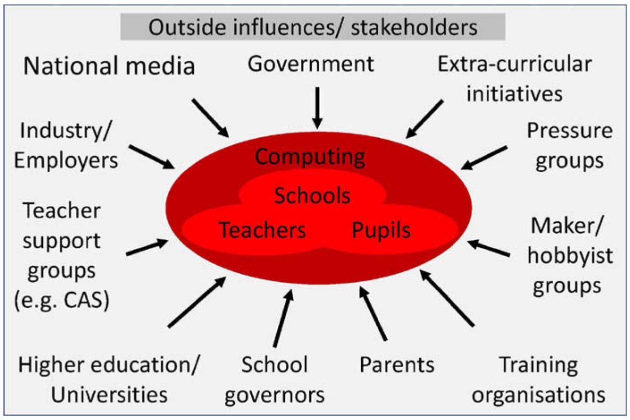


**Figure 1:** Groups influencing computing education in school.

in contrast to previous curricula which had been more prescriptive. The lack of detail has meant that a range of other parties have had some influence on how it has been implemented. Government in England has partially funded support for teachers through the Network of Teaching Excellence in Computer Science (NoE) (see Section 3.2), a Computing At School initiative.

## 3.2 Computing At School

Computing At School (CAS), part of the BCS, played a significant role in lobbying for the change in curriculum as well as providing support services and consultation. Funded by a variety of industry partners, it has produced a range of resources to support teachers in transition to the new curriculum. These programmes included the primary (K-5) Barefoot website and Barefoot free CPD sessions for primary schools and Quickstart primary (k-5) and Quickstart secondary (6–8) handbooks.

CAS is a grass-roots organisation that has grown organically since its inception in 2008 [23]. Its members can be seen to be a community of practice [17]. Computing At School rallied community support through its master teachers, hubs and lead schools sharing resources through its online portal. Building on the foundation of the local hubs, CAS has established, with support from the Department for Education in England, a professional development programme called the Network of Teaching Excellence in Computer Science (NoE). The Network of Excellence is based on local, face-to-face, peer-to-peer delivery through regional centres, based in universities and CAS Master Teachers based in schools, and CAS Hubs made up of groups of teachers who meet regularly to share experiences. CAS Master Teachers volunteer to support other teachers, and although unpaid the role gives some status and recognition in their schools and beyond [23]. Figure 2 shows the structure of the NoE.

## 3.3 Universities

Computer science departments/academics have an obvious interest in the introduction of Computing in school, through their own teaching experience in this area. Many may have been involved in outreach activities prior to the new Computing curriculum. From this experience they offer resources to teachers and training sessions for teachers. Universities are key contributors to the NoE (see Figure 2) and work to support teachers. Education departments are also very involved with the Computing changes in their role as pre-service teacher trainers in Computing. The latter group may have more understanding of pedagogy that is applicable in school. It is important to avoid the assumption that children can be taught Computing in the same was as undergraduates – this is not the case.

## 3.4 National media

Interest from the national media, governments and interested and pressure groups added further complexity to a landscape in which teachers were perhaps not always well placed to be discerning consumers of curriculum content or delivery approaches. The changes have gained media interest – from announcing that ICT was doing children a disservice in 2012, to announcing that the whole curriculum was to be based around "coding" in 2014, and more recently to question the success of the changes. The impact of this intense interest can be confusing for teachers and also mean that parents may have a distorted view of what is happening in school.

## 3.5 Industry and employers

Much has been written about the need for a more technological workforce and the need to produce more computer programmers and workers for the IT industry. It could be seen that the purpose of introducing computing into school was to generate more highly skilled employees, and certainly the changes have been met favourably by employers and industry bodies, who have in some case generously funded initiatives and resources to support teachers. They do have a different perspective and agenda, and in developing resources need to work closely with educators to enable effective pedagogy.

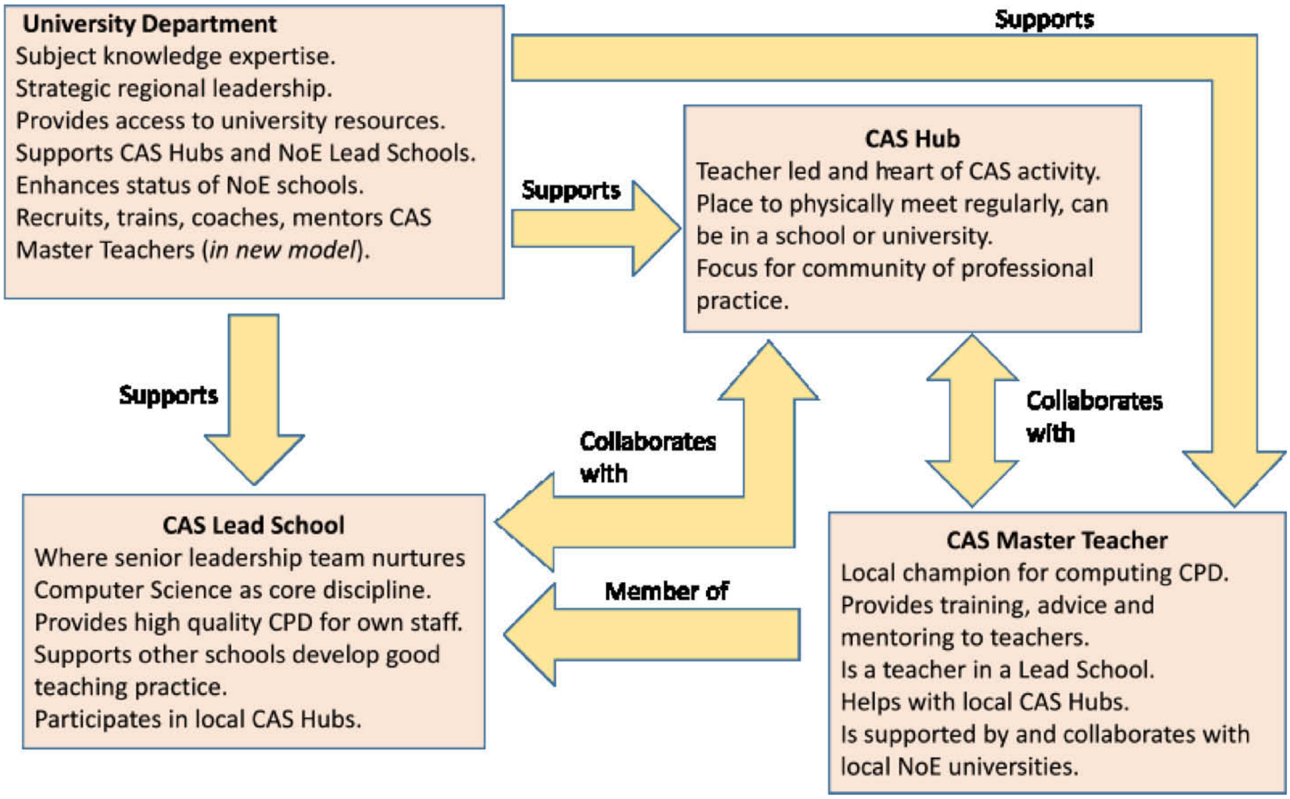


**Figure 2:** CAS Network of Excellence.

### 3.6 Resource developers

Other groups also have an interest in computing in school, including educational technology companies, local authority and other legacy education teams, charities and maker communities, after-school and other informal education groups and training providers. All of these groups have created new curriculum material on programming, computational thinking and computer science concepts. Each had their own reason for involvement, their own vision of what should be taught and incorporated different pedagogies for delivery. At the same time, existing resource providers amended legacy ICT planning to include programming and other CS concepts. A small number of early adopter teachers and local authority teams shared planning which they had been using in school prior to the curriculum changes.

The urgency to produce resources was particularly exacerbated by the brevity of the regulatory statement of the new computing requirements in which intentionally no pedagogical guidance was provided and only high level target statements were provided. Perhaps at this time of initial change, when there was little class-based research of how to teach computing, this lack of direction led to a pedagogical vacuum. This vacuum was filled by a plethora of approaches, not necessarily proven through research. Some approaches were derived from training adults or university students, others were approaches suited to delivery by industry volunteers, others were techniques particularly suited to automated on line teaching systems. How this proliferation of resources and approaches from such a diverse group of providers has impacted on teaching and learning is not clear, but schools and teachers can feel overwhelmed by choice but at the same time lack a clear steer.

## 4 Early experiences of implementing computing in school

The new Computing curriculum has been in place for three years and teachers are starting to become familiar with it. In other areas of the UK, curricular vary as the increased focus on computer science in the curriculum is being worked out in different ways. Recent reviews of the implementation of the curriculum have identified both positive and negative aspects [5, 26, 29]. In this section we consider early experiences and what it tells us about the interest and motivation of pupils and attitudes and confidence of teachers.

## 4.1 Interest of pupils

Industry-led surveys suggest that pupils enjoy the creative aspects of working with a variety of software packages and tools to design and develop computing solutions and are interested in finding out how computers work [5, 26]. Pupils continual exposure to technology in their daily lives can be explained and put in context in lessons in school.

A recent study by the telecom company BT [5] surveyed 400 teachers and conducted 5 in-depth case studies around schools and settings using the Barefoot[2] resources. The study found that primary teachers using the Barefoot resources reported that children using these resources were less "needy" and were developing computational thinking skills, thinking for themselves and building resilience. In this study, every teacher (100 %) said that their pupils enjoy using technology in lessons. One in six (16 %) teachers reported that pupils liked technology because it is creative, while one in five teachers felt that children liked using technology to problem solve and discover how the technology itself works (20 %) [5, p. 41]. 22 % of the teachers reported that children found using technology fun and engaging and the same number that it was familiar to them from use at home. This study highlights that both teachers and children can enjoy the creative elements of computing in primary. There is less evidence that the Computing curriculum is effective in terms of skills and knowledge development.

One study which attempted to provide this, albeit in an extra-curricular environment, was an independent study of Code Clubs. It looked at the impact of these extra-curricular clubs in primary schools on both cognitive skills development and interest in computer science using a randomised control trial (RCT) [26]. As part of the RCT, schools were required to deliver their Code Club over three terms to pupils randomised to the intervention group. Drawing on freely available Code Club UK projects, school leads were asked to deliver one term each of Scratch, HTML/CSS, and Python to pupils attending Code Club for the entire academic year. Bebras[3] tasks were used to measure the computational thinking skills at the end of the trial. 252 pupils completed the end of trial assessment. The findings demonstrated that attending the clubs for a year did improve skills in the programming environments, but not, surprisingly, in computational thinking. Pupils also completed attitude surveys which demonstrated that attending Code Club for an academic year results in pupils' increased usage of computers, as well as positively impacting on how good they feel they are at making things with code. However, rather surprisingly, interest shown by the intervention group was lower: at the end of the project Code Club pupils were a little less interested in learning about coding and learning about coding languages than the control group pupils. This study relates to an out-of-school initiative: when considering the teaching of computing in the curriculum, we can imply from this that interest in computing may not necessarily increase with exposure and the way that the subject is taught will have an impact on retaining interest and motivation. We suggest that the results of this study point to the fact that we need more research into pedagogical strategies used in Computing lessons, a fact underlined by the most recent Royal Society report [29].

The gender imbalance in Computing is well known and has been documented widely. One of the aspirations around introducing computer science to younger children is that the subject will be understood better by all children before they need to make choices, and that this understanding will reduce the impact of the negative societal impressions of women in technology that seem to influence choices of subjects. However a recent report on those offering and taking post-14 examinations in computing shows that computing has one of the proportionally lowest female intakes of any qualification at 14–16 (16.1 % female) and at 16–18 (8.6 female) [15]. We should continue to try to find out how to effectively engage girls: for example, in the context of extra-curricular learning, a recent report from Scotland indicated that holding single-sex events to attract girls to coding clubs does not increase continued interest by girls and that instead having a social contact who has a connection or interest in coding was a more likely indicator of engagement [21].

In terms of particular approaches that interest students, recent UK research indicates that physical computing creates interest and engagement [24] and unplugged activities[4] provide generated a high level of understanding for very young children [32].

**2** https://barefootcas.org.uk/

**3** http://bebras.uk

**4** Unplugged activities are those that teach computer science concepts in a creative way without using a computer.

**Table 1:** Teachers' attitudes to teaching computing from the 2016 CAS Survey [7, p. 14].

| | Agree strongly | Agree slightly | Disagree slightly | Disagree strongly |
|---|---|---|---|---|
| I enjoy teaching the computer science elements of Computing | 74 % | 21 % | 4 % | 2 % |
| I have had to work hard to develop my subject knowledge | 59 % | 28 % | 9 % | 4 % |
| Generally my students enjoy Computing | 53 % | 38 % | 8 % | 1 % |
| I have gained confidence in teaching Computing since …2014 | 54 % | 36 % | 7 % | 3 % |
| I find some of the concepts and programming difficult to teach | 30 % | 39 % | 20 % | 11 % |
| I know where to find good quality resources for Computing | 42 % | 44 % | 11 % | 2 % |

## 4.2 Teacher attitudes

The new curriculum has had a significant impact on the lives of teachers. Secondary teachers who were trained to teach ICT are now teaching Computing despite not having any formal training [4]. Primary teachers are trained to teach across all subject areas which now includes Computing from age 5–11. Specialist secondary pre-service teachers are trained at universities of via employment-based schemes once they have gained their (computing-related) degree, via a post-graduate course that lasts one year. The teacher training programme changed from ICT to Computer Science/Computing in 2013 immediately prior to the curriculum changes. However recruitment of new teachers remains a challenge. Qualifications for students aged 14–18 have changed since 2014 to reflect the new curriculum focus, with more emphasis on computer science.

There are over 3300 secondary schools and 17000 primary schools in England [3] and supporting all teachers through this significant curriculum change is challenging. It is important to have confident and well-qualified Computing teachers but 32 % (n=109) of primary and 44 % (n=265) of secondary teachers lack confidence in the later stages of the curriculum, according to the recent Royal Society report, After the Reboot [29]. In another study of 400 primary teachers 98 % said they regarded it as part of their job to equip children for a digital world but only 25 % strongly agreed that they felt prepared to do that [5]. There is clearly a need to support teachers to develop confidence and familiarity with the material that is now being taught.

Other teacher surveys carried out within Computing At School report higher levels of confidence of teachers with the teaching of Computing. For example, in 2016, the survey (written and analysed by the first author) was completed by 822 teachers, primarily members of Computing At School. Teachers were asked to relate their confidence in teaching the Computing curriculum on a scale from 1 to 10. 88 % teachers scored their confidence as 5 or more (2 % more than 2015) and 74 % as 7 or more (an increase of 7 % from 2015) – with teachers reporting an average confidence value of 7.3. When comparing primary and secondary teachers self-reported confidence of the survey respondents was similar in both phases, with primary teachers reporting more confidence at 7 or above (81 % of primary teachers compared to 71 % of secondary teachers).

The same survey also asked teachers about their attitudes to teaching computing and whether they experienced difficulties. The results are shown in Table 1. Teachers completing this question gave positive responses in terms of their enjoyment of teaching Computing (95 % of teachers agreed (slightly/strongly) that they enjoyed teaching the computer science elements of the Computing curriculum); however at the same time, 69 % of teachers agreed (slightly or strongly) that some of the concepts were difficult to teach. 90 % of teachers agreed that they had gained confidence since the introduction of the curriculum (at the time of the survey in its second year) and as can be seen elsewhere in the survey, 87 % agreed that they had to work hard on their subject knowledge. 95 % of the teachers said that their students enjoyed learning Computing.

In another study, qualitative research into the challenges reported by teachers (n=339) in terms of the teaching of computing [22] generated the following most frequent key themes:
- Teachers' own subject knowledge
- Students lack of understanding of content
- Technical problems in school
- Differentiation to meet different levels of ability
- Students willingness or ability to problem solve

[22, p. 479]

Teachers highlighted challenges that related to both their own difficulties with teaching computing content and students' difficulties in understanding. There were a range of technical issues referred to also, around lack of technical support in school and obstacles around acquiring the resources they needed. The study refers to data gathered in 2014 so further research is needed. What is clear is that teachers' experiences do vary widely, as identified in the Royal Society's After the Reboot report, where it was noted that some teachers are confident and favourably inclined to Computing, while there are other groups of teachers who still need significant support [29]. One of the challenges is providing targeted and sustained support to teachers who are still adapting to the new curriculum.

## 5 Classroom activities

In this section we give two examples of the types of activities that have been developed to support the teaching of Computing in school. The first illustrates how computational thinking is a core component of the curriculum and how it can be related to cross-curricular teaching. The second example incorporates physical computing, which is growing in popularity in UK schools.

### 5.1 Focus on computational thinking

The Computing curriculum in England highlights computational thinking, and this is presented in many of the primary and secondary materials as sets of specific skills including abstraction, algorithmic thinking, generalisation and decomposition [6]. Many resources have been developed to support the development of computational thinking skills, and for primary schools, a significant project to support computational thinking in school is the Barefoot project (see Figure 3)

The Barefoot project includes resources and training for primary teachers and, given the nature of primary teaching, focuses on computing being integrated across the curriculum. Having activities that embed computing in different subjects can help computing seem more relevant as it provides a context for the activity. One example is the solar system activity in the Barefoot materials (see Figure 4).

The solar system is something that pupils will learn about in science and geography lessons. In this activity pupils develop a program which simulates the inner and outer planets in the solar system. Starting with a model program that they can run showing the Sun and the moon they can learn that computers can be used to simulate things that happen in the physical world. Pupils are then able to design another planet and consider how its movement could also be simulated. This introduces pupils to design and modelling, key aspects of computer science, as well as identifying, understanding and tracing the use algorithms in the existing code. Moving on they can modify the Scratch code to create new functionality.

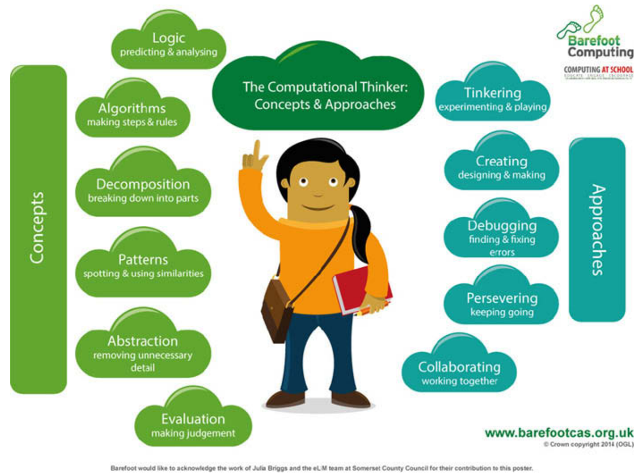


**Figure 3:** Computational thinking focus in the Barefoot project.

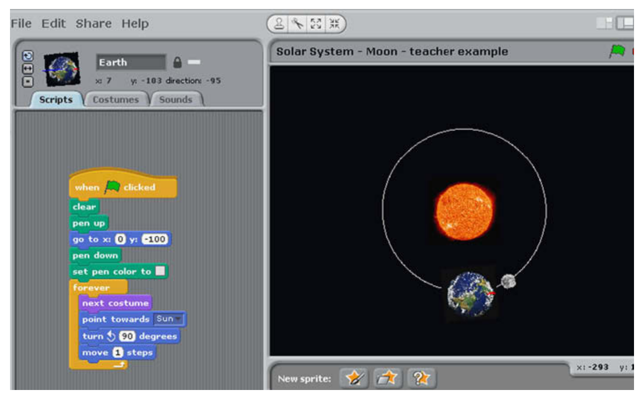


**Figure 4:** The solar system activity from CAS Barefoot.

In this way we can see that other subjects can provide a context for the learning of computing that makes it relevant and links to other aspects of the curriculum. Planning and design are skills that need to be learned in other subjects too. Evaluation of potential solutions is a key aspect of computer science that can be also seen in the development of mathematical thinking.

### 5.2 Focus on physical computing

The UK has a considerable history in the development of personal computers in the 1970s and 1980s and many adults feel nostalgic about this period. Capitalising on the nostalgia around the BBC micro, the BBC micro:bit project saw a small programmable device given to each 11-year old in the UK; the device can be used to create a whole range of physical projects – which give children an insight into the creative aspect of physical computing [24]. This development has made physical computing very accessible for

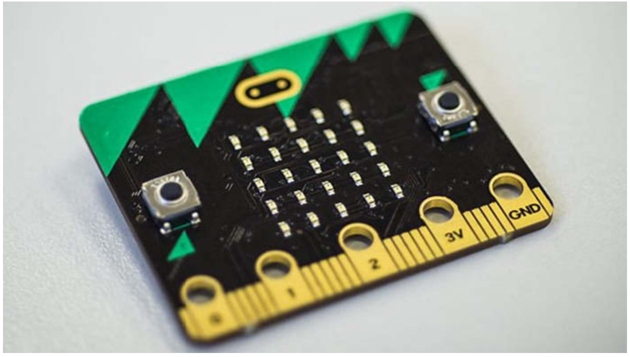


**Figure 5:** The BBC micro:bit.

many teachers and sparked an interest in other similar devices and creative, digital ‘making’ activities.

The BBC micro:bit (see Figure 5) is a pocket-sized codeable physical computing device. It has a built-in display, buttons, motion detection, temperature and light sensing, and it supports Bluetooth Low Energy (BLE) wireless communications [2] and is designed to be used within the curriculum with children aged 11–12 (although it is now used with both younger and older children).

Teachers have developed materials or used existing resources to enable pupils to develop a range of creative projects, from creating a pedometer to a virtual pet. Programming skills are developed in either Python, Javascript or in a block-based language, and pupils gain a greater understanding of hardware components that can be attached to the micro:bit. This type of activity illustrates the importance of maintaining a creative element in the teaching of computer science and demonstrates that computing in the curriculum can be engaging and relevant. Teachers have responded well to using the micro:bit in school with 11 and 12 year old children, with different teaching strategies employed [25].

Physical computing can help teachers with the teaching of text-based programming languages, which are part of the Computing curriculum from age 11. Text-based programming can be cognitively very challenging for children just learning to program, particularly where the language does not have built-in support [16]. Physical computing can provide instant feedback and a motivational environment.

# 6 Challenges

The recent report from the Royal Society has highlighted some of the challenges faced by the implementation of the new Computing curriculum [29]. Despite the developments that have been made in integrating computer science into the school curriculum, there have been, and still are, challenges. These will need to be tackled by a combination of increased awareness, funding and research that feeds back into schools.

Key challenges are:
- Teacher confidence
- Inclusion and diversity
- Breadth in the curriculum
- Need for research around pedagogy

## 6.1 Teacher confidence

As reported earlier, some teachers still lack confidence in teaching Computing. Initiatives like Computing At School rally teachers and support the sharing of resources and peer teaching for those teachers that seek help. However, there are many teachers who cannot access the available support or are not aware of it. To change this, more top-down support from government is needed, with a more comprehensive professional development programme [29]. Teachers already work to capacity in demanding jobs and face many pressures. The changes have been fast-paced and extensive and it has been difficult for teachers without a prior background in computer science to quickly up-skill in this area. Although addressed in part by the initiatives described above, these initiatives do not reach all teachers and learning the necessary skills and knowledge takes time.

## 6.2 Inclusion and diversity

We have seen earlier that there is a gender imbalance once students can elect whether to specialise in computing (age 14). This imbalance is also seen with students from lower socio-economic backgrounds, who are similarly less likely to select Computing [15]. Incorporating mandatory Computing in the curriculum from an early age may have a positive impact on this situation over time, but it is important also to consider the way we teach in order to ensure that computing is accessible and interesting to all. This can be a challenge as we do not have sufficient research or past experience to yet know about appropriate pedagogies. More research on engaging under-represented groups in Computing is needed, and in particular we need to modify Computing pedagogy and tools so they better fit a diverse audience [8].

### 6.3 Breadth in the curriculum

Being able to offer a broad and balanced curriculum that includes computer science, digital literacy and information technology as laid out in the national curriculum in England can be challenging. Having a curriculum that is low in detail means that the balance is interpreted differently in different schools: in the interest of equity we wish to ensure that all children are given equal opportunities in school. Children have an entitlement to learn all three areas. It has been identified that having qualifications too focused on computer science at upper secondary school level has the potential to affect uptake [29].

### 6.4 Research into pedagogy

Computing was originally introduced into school in the 1980s (and then removed) with a focus on mathematical and computational learning using exploratory approaches – following the work of Seymour Papert [19] who was clear that children learned in a different way to adults. We are now revisiting computing in the curriculum and need research that builds on this, and extends our understanding of how to teach computing effectively. For example, one of the problems with introducing computing to young children is that it can seem fun, engaging and creative until some of the “hard” problems are reached. This can happen, for example, when Scratch programmers use a ‘copy code’ or exploratory approach then move into a text-based language and are required to write code themselves without suitable scaffolding. New research in primary computing education is adding to the body of knowledge around misconceptions and unhelpful habits [10, 11]: this research is at an early stage and much more is needed to add to this emerging body of knowledge. Computing for all will only succeed in the long-term if we have a fuller understanding of how to learn and teach it.

## 7 Conclusion

Education is subject to continual change, particularly when it is politically influenced [1]; it is pupils that bear the brunt of curriculum changes as the landscape shifts while they are in education. One of the key lessons learned from the last three years of Computing in England is that change does not happen overnight. Pupils, teachers, parents and school leaders all need time to adjust to a new subject in school. From the evidence we have so far, it appears that pupils are engaged by computing: and that accessibility for all students requires a broad and pedagogically-sound curriculum. We need to continue to gather evidence around how children learn Computing, how to maintain interest and engagement and how to make the content accessible to all children. A programme of rigorous research is needed to ensure positive outcomes for all.

Work to support teachers around the implementation of the curriculum is on-going and both schools and teachers need time to adapt and take ownership of the changes. School leaders should be encouraged to see computing as a high-value school subject. The group Computing At School, made up primarily of volunteers, is working to support teachers via peer-to-peer initiatives which have some funding by the government. Until more support is available to extend this help for teachers more widely, provision of a high-quality computing education in primary and secondary schools may still be patchy. Increased funding from government is needed to improve this situation.

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